

Using web-based textbook to improve students' understanding of materials science

Monika Bubacz and Deirdre Ragan

The Citadel, Charleston, SC

Abstract

The Citadel's materials science instructors evaluated a web-based textbook from zyBooks as a replacement for a traditional hardcopy. The same textbook on the web is presented as a "less text, more action" resource that consists of questions sets, animations, interactive tools, and embedded homework. This website with learning content was also linked to Canvas LMS, The Citadel's Learning Management System, which became mandatory during the COVID pandemic. The instructors administered zyBooks learning participation activities, which were due before the class meeting time, promoted engagement, and allowed active monitoring of students' preparation. The participation was easily converted to grades in Canvas. In-person / in-class quizzes and tests were built to include examples and activities from zyBooks thus encouraging and measuring students' engagement. Exam grades were not notably altered. End-of-semester survey results were mixed, with students evaluating the zyBooks as useful for learning yet still not preferring it to a traditional textbook.

Keywords

Materials science, web-based learning.

Challenges of Teaching Materials Science

Materials science is important to engineering as it explains materials behavior and creates a backbone to engineering design. Current undergraduates are growing up in a time when materials innovations have enabled a myriad of technologies and devices that have changed their lives. In the future, these students will be responsible for finding solutions that address our growing need for sustainable, environmentally friendly, and affordable energy, water, and clean air, as well as all the goods required for a technology driven society and economy.¹ Developments in advanced materials and materials engineering will help create new sustainable environments.² In spite of the importance of materials science concepts, however, materials courses can be challenging for undergraduate engineering students as these courses are based on chemistry and physics. Many of the concepts in materials courses can be difficult to visualize and comprehend, i.e., electron configurations, atomic bonding, crystalline structure and its behavior under loading, synthesis, and processing. Given the complexity and nanoscaled dimension of interactions, computer-based tools could augment learning.

Moreover, current students grew up around laptops, Wi-Fi, video games, text messages, tablets, and mobile phones. They are accustomed to, and expect, access to a significant amount of information in seconds. For example, they expect that books and articles be accessible online while they are traveling, eating, waiting, and studying. This generation is open to the use of technology; they are quick, impatient, resilient, and interactive.³

Web based resources greatly enhance teaching capabilities, especially in case of materials science since it incorporates aspects of physics, chemistry, mechanics, and manufacturing. Adding PowerPoint slides with photos and hands-on lab activities greatly helps to replace the need for tedious board notes with three dimensional sketches and often detailed charts, however using well prepared web-based resources helps visualize the transition from atomic to crystalline structure to macro-scale behavior under load or production. Web based open-source collections of calculations, animation, simulations and quizzes produce additional resources enhancing different types of learning.

Electronic and online textbooks also present two possible tangible benefits to the students: accessibly and cost. As students generally have an electronic device, i.e., phone, laptop, or tablet with them at all times, access to the text does not require carrying the 900+ page book with them. Additionally, the cost of the electronic texts is less than that of the printed text.

Many instructors are hesitant to move towards electronic texts as they believe studies have shown that comprehension is higher through print documents. However, multiple modern studies with individuals who are comfortable with reading other content on electronic devices have found positive impacts through electronic texts. Electronic textbooks can be as effective as traditional textbooks and the interactivity of online texts potentially engages students better.^{4,5}

For years, textbook publishers offered online or electronic versions of textbook with an ever-increasing depository of exercises and solutions for use by instructors. This evolved into web-based quiz and test depositories that allowed self-grading. Many resources contained software codes and hyperlinks to animations, videos, and interactive tools. In 2012, zyBooks initiated combining minimal text from books with online content created “web-native interactive content”⁶ to enforce student learning by doing. With the use of zyBooks, researchers have reported improved student performance, engagement and confidence with the subject matter⁷, motivation⁸, and grades⁹. Additionally, it is anticipated that automated recording of student online engagement with the textbook would allow instructors to make reading mandatory before class and that built-in simulations, animations, and embedded tools allow for more immediate learning experience, creating better-prepared students in class.

zyBooks in Engineering Materials course

The Citadel’s Engineering Materials course instructors made an online zyBooks Engineering Materials text the required book and obtained a 100% student subscription rate. For the course, assignments of zyBooks text sections are integrated into Canvas LMS and linked with Canvas gradebook. Each class-meeting day, a reading and a set of participation activities from one chapter are assigned to students. The assignments are required to be completed before class time. Participation activities include animated graphs and figures; step-by-step example problems and calculations; and interactive multiple choice, true/false, and matching problems with answer feedback. For this work, zyBooks participation is scored based on the percentage of activities completed not on the correctness of the answers. Additionally, zyBooks tracks amount of time the student spends in the text. The scores were collected from 58 students in two course sections. Figure 1 presents average scores for participation activity completeness and for recorded reading time. Days 3, 6, 8, 12, and 15 were based on text sections for which zyBooks did not have any participation activities and were reading only assignments. Days 9, 16 and 24 were based on

exam review assignments constructed from previous text sections and did not record the time students spent in their review.

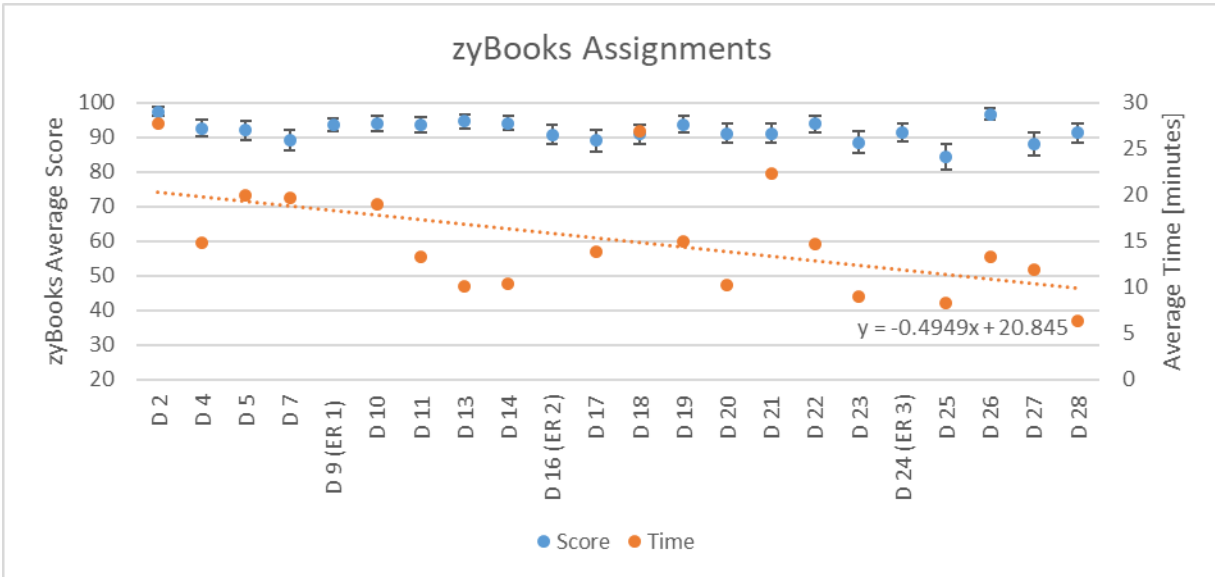


Figure 1. zyBooks Participation Score and Time Spent Averages

It is noted that as semester progresses the activity scores remain at around 90% while the time spent doing the reading and activities decreases on average from 20 to 10 minutes per assignment. This decrease may be associated with decrease of students' available time as the semester progresses.

Figure 2 shows weekly homework grades. The trend line shows slight but steady score decrease. This can be attributed to increased difficulty of assigned problems and should not be consider problematic as long as the average stays above 80%.

Quiz (Q) and exam (E) grades are presented in Figure 3. Quizzes 1 and 2 took place before Exam 1 (E1); Quizzes 3 to 5 took place between Exam 1 (E1) and Exam 2 (E2). Final Exam (FE) was similar to previous years' tests in order to compare students' performance in this and past course offerings.

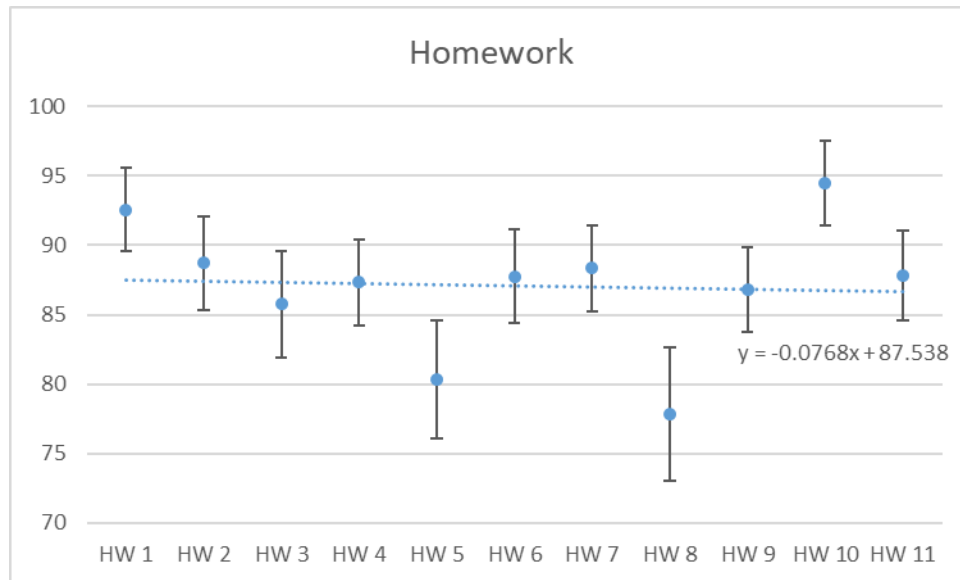


Figure 2. Homework Averages

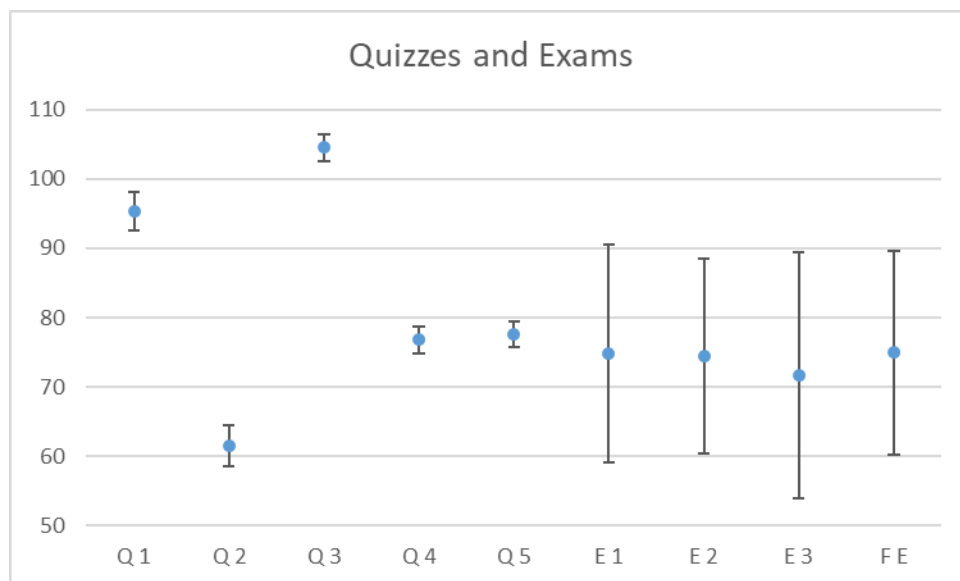


Figure 3. Quiz (Q) and Exam (E) Averages

Quiz questions were taken from the zyBooks content. Quiz 2 (Q2) contained only true/false questions based on zyBooks participation activities and previous class content. Either the mode of questioning or the nuances of the material were challenging, producing the worst student quiz performance. On the other hand, Quiz 3 (Q3) shows the best student quiz performance. It contained solely word matching problems and included bonus points designed to improve grade average after low scores in Quiz 2. An average above 100% illustrates that students performed well with this mode of questioning and took the advantage of extra points. Quizzes 1, 4, and 5 all contained a mixture of multiple choice, true/false, and word matching questions. The quizzes

cannot be compared to quizzes from previous years due to the difference in quiz content and question type.

Exams (E1, E2, and E3) and the final exam (FE) were similar in content to previous course offerings. The average exam scores in previous years were similar, in the 70-80% range, suggesting that the zyBooks had no measurable impact on exam performance.

The semester concludes with a cumulative final exam, with the same general course and exam content since 2014. The comparison in Figure 4 of final examination grades and average student exit GPA shows no improvement this year with the use of zyBooks.

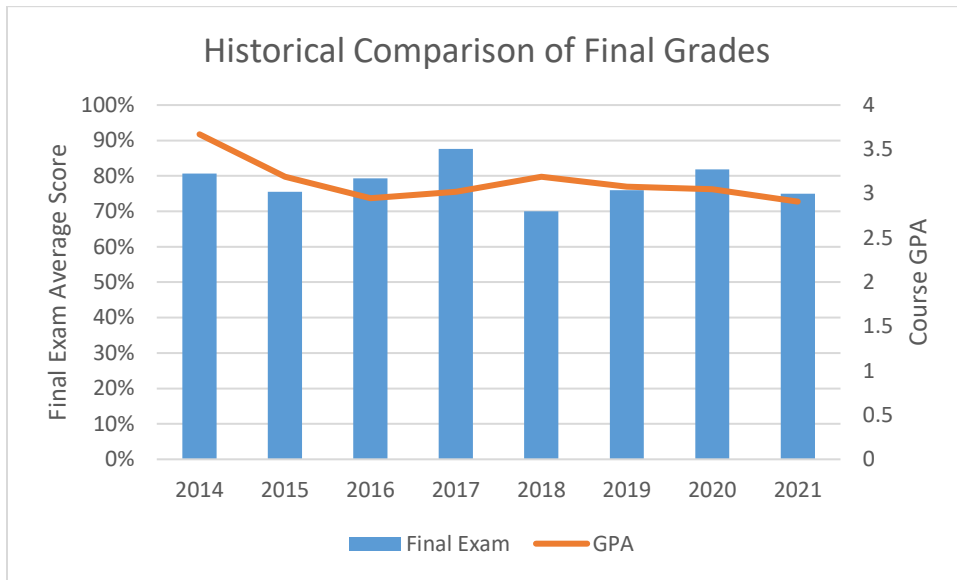


Figure 4. Historical Comparison of Final Exam Averages and Exit GPA

At the end of the semester the students filled a course specific survey containing questions related to instruction, course resources, and laboratories. The results of questions related to zyBooks are presented in Table 1. Seven questions used 5-point Likert scale ranging from 1 - Strongly Disagree to 5 - Strongly Agree. These questions were followed by two open-ended questions summarized in Table 2.

Table 1. Results of End of Semester Student Survey, Likert Scale Questions

Survey Questions	Average
Q1. I was pleased that zyBooks was part of the assigned course materials.	2.65
Q2. I feel that learning questions and assignments helped me understand course materials.	3.44
Q3. I feel that interactive figures and animations helped me understand course materials.	3.42
Q4. I feel that zyBooks makes learning easier through simple content organization.	2.83
Q5. I used the step-by-step examples to double-check my comprehension.	3.07
Q6. I would recommend using a zyBook to a friend or instructor.	2.67
Q7. I would prefer a traditional hardcopy textbook for this course.	3.02

Table 2. Results of End of Semester Student Survey, Open-Ended Questions

Q8. What did you find useful about the zyBook interactive textbook?	Q9. What did you find most displeasing about the zyBook interactive textbook?
<ul style="list-style-type: none"> - interactive activities - animations, matching and multiple choice questions - questions explained why answers were right or wrong - good test review tool - it is much cheaper than the actual textbook - ease of access 	<ul style="list-style-type: none"> - length and repetitive nature - time consuming and not helpful for those who do not learn like that - busy work and extra material for the course - interface on mobile devices is difficult to use in some cases which is annoying - some grades received do not actually transfer to Canvas

The survey results showed that students were slightly displeased with zyBooks assigned activities and reading as part of their grade and learning from this type of resource (Q1=2.65). They seem unlikely to recommend it to a friend (Q6=2.67) yet, they also felt neutral about a preference for a traditional hardcopy text (Q7=3.02). We notice a slightly positive response to using zyBooks activities to better understand the material and prepare for tests (Q2, Q3~3.4). In short, while the students on average slightly agreed that the zyBook helped with understanding and learning, they did not prefer it to paper textbooks. Along that line, a common theme in

answers to the two open-ended questions amounted to “I need to be taught material. Reading it isn't very helpful.”

Discussions

The implementation of zyBooks edition of previously required textbook introduced teaching and learning flexibility to both students and instructors. The instructors were able to program the curriculum as they see fit and create daily and weekly study sections that fit an academic calendar distinct to the institution. Quizzes were based on both recently covered and new material and enforced the importance of students' preparation before each class. Quizzes allowed instructors to check quickly for any 'muddy points' and adjust the lecture plan. Based on quiz and homework scores, more time was spent on in-class activities that put concepts into practice.

The students were predisposed to use the web-based material even if only for browsing for answers to assignments. The thorough usage reporting tools allowed instructors to monitor students' involvement and respond with additional assignments as needed. It was also feasible to convert students' engagement into grades and stimulate usage of provided learning tools.

Not all feedback on the use of the zyBooks online textbook was positive. Students noted that reading text and examples was not their preferred mode of learning. Additionally, students and instructors noted challenges with looking up material in different sections of the text. Previous research studies¹⁰ have noted similar frustrations.

The analysis of student participation and grades shows that students participated in assigned activities and were passing additional assignments without significant issues. zyBooks participation scores averaged around 90% with time spent in a range of 10-20 minutes for each class. The average time spent on the readings and exercises showed a decreasing trend as the semester progressed. The homework average stayed around 85% and the exam average around 75%. The final exam average and grade average did not show a significant change compared to past seven years. The students expressed dissatisfaction with the amount of assigned reading and web-based activities. The instructors will evaluate the next year zyBooks textbook version and adjust the assigned content in future course offerings.

Conclusions

Materials science courses as part of engineering curriculum often create student backlash as the courses are based on multiplex science concepts and little calculations. Many of these concepts require visualization of information that is time and temperature dependent and of three-dimensional structures that are rotated in space. The instructors were pleased to utilize a zyBooks textbook to drive and monitor student learning and engagement. The zyBooks multi-media tools greatly enhance this visualization while probing student understanding at the same time. The students are exposed to key concepts while completing the participation activities even if they read very little of the text. The instructors are looking forward to additional zyBooks tools and activities that are being developed for future editions and will adjust course content and assignment based on current students' feedback.

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Monika Bubacz

Dr. Monika Bubacz is a Professor in the Department of Mechanical Engineering at The Citadel. She received both her B.S. and M.S. in Mechanical Engineering from Poznan University of Technology in Poland, and the Ph.D. in Engineering and Applied Science from the University of New Orleans. Before her current appointment, she has worked for Mercer University in Macon, GA, Pittsburg State University and Center for NanoComposites and Multifunctional Materials in Pittsburg, Kansas and Metal Forming Institute in Poznan, Poland. Her teaching and research interest areas include materials science, polymers and composites for aerospace applications, nanotechnology, and environmental sustainability.

Deirdre Ragan

Deirdre Ragan is an Assistant Professor in the Department of Mechanical Engineering, as well as the director of the Honors Program, at The Citadel. She holds a B.S. in Materials Science and Engineering from Rice University as well as a M.S. and Ph.D. in Materials from the University of California Santa Barbara where she studied stresses in thin films. Now she enjoys teaching upper-level undergraduate and graduate Materials courses, Honors courses, and mentoring students. Her research interests include materials science, the neuroscience of learning, humanitarian engineering, and undergraduate research involvement.